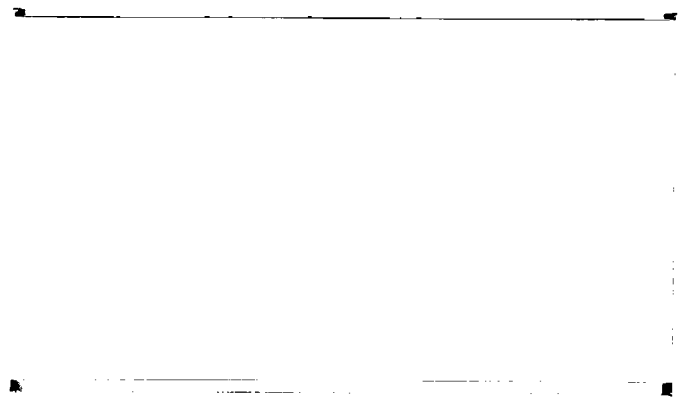
File P-154

THE MM-100 OPTICAL READING COORDINATE COMPARATOR.



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THE MM-100 OPTICAL READING COORDINATE COMPARATOR.

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30 April 1956

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MM-100 COMPARATOR OPERATING INSTRUCTIONS.

The comparator has been designed for precise measuring with a least reading of one micron (.001mm). Throughout the construction, assembly, and final adjusting, every effort has been made to make this one micron significant in measurements made with the comparator. However, even assuming perfection in the machine, a casual approach to its use will never result in such precise measurements. The correct approach, consistantly followed, is required for good measurements.

The film spool brackets will accommodate standard 70mm film spools, or film may be wound onto one of the film cores furnished. The film is passed under the film idler roller; over the glass platen, the pressure plate having been removed; under the opposite idler roller; and onto the take-up spool. The film pressure plate is put in place, over the film, with the beveled notches referenced to the pressure plate clamps. The film pressure plate release arm is moved to the right to clamp the pressure plate against the film.

The swing tangent screw is used to orient the film format with relation to the X travel.

With the X and Y slow motion clamps released, both carriages are free from the slow motion drives, and may be manually pushed through the full 0 to 100mm range. In use, the point on the film to be observed is approximately positioned under the microscope by hand, the slow motion clamps are tightened and final positioning is done with the slow motion drives. The Y slow motion clamp is a knob which is turned clockwise to tighten. The X slow motion clamp is a lever which is pushed rearward to tighten.

Both eyepieces are focused by rotating the eyepiece lens housing. Any one of four reticles in the film microscope eyepiece may be selected by backing out the film microscope eyepiece lock several turns and turning the small knurled knob at the top rear of the film microscope eyepiece.

The film microscope is focused by rotating the focus knob. The focus clamp must be released for focusing and must be tightened before any measurements are made.

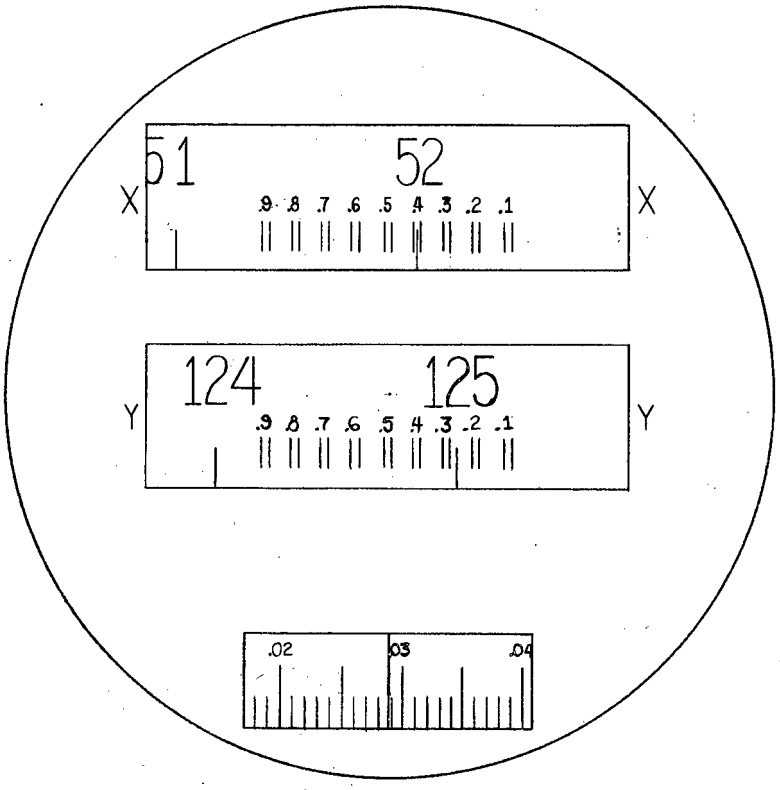
Great care must be taken in achieving correct focusing of the film microscope. The eyepiece should be focused separately, with the objective moved out of focus. Correct focus has been obtained when there is no obvious effort of the eye to accomodate when quickly shifting from a distant object to the reticle image in the eyepiece. The objective is then focused for sharpest image, followed by refined focusing to remove parallax. Some refinement of the eyepiece focus may be necessary along with the objective focusing.

All final settings of the X and Y slow motion drives and the swing tangent screw should be made with a clock-wise rotation. It does not matter from which direction the micrometer setting is made, as long as it is made from the same direction each time.

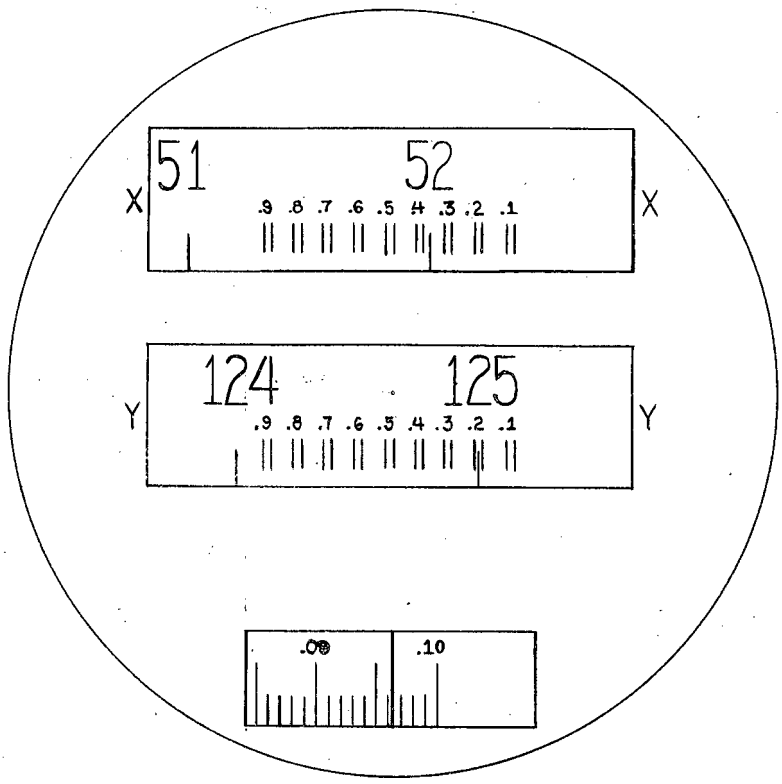
The main scales (X and Y) are divided at 1mm intervals. The X scale has each millimeter numbered, from 1 to 100. The Y scale is numbered from 100 to 200 to reduce the probability of confusing X and Y readings when recording. The eyepiece reticle is divided at 0.1mm intervals and the micrometer scale reads directly to 0.001mm.

The optical micrometer is operated by the micrometer knob at the left rear of the instrument. Turning the knob causes a weak prism, or wedge, to move along the optical path, which causes an apparent displacement of the main scale lines. The micrometer scale is ruled on a piece of glass attached to the wedge. Thus the micrometer scale, moving with the wedge, provides a measure of the displacement of the main scale lines.

In taking a reading the micrometer knob is rotated until the main scale line is set symmetrically between one of the pairs of the reticle lines. When this is done the reading is obtained by adding the figures of the main scale division to that of the reticle division. The micrometer reading is then added in the subsequent decimal places. The two views shown illustrate clearly how the readings are obtained. (Fig. 1)



X READING = 52.429



Y READING = 125.296

Fig. 1

HILGER & WATTS LTD.

SCALE CALIBRATION

1 0 - 100mm. No. 592
1 100 - 200mm. No. 591

These Scales have been calibrated against a master scale which has itself been calibrated against gauge blocks, and the results can be relied upon to within ± .5 micron.

The following calibration gives scale errors at 5 cm. intervals.

0-100mm.			100-200mm.		
Interval mm.	Scale Length mm.	Interval Error mm.	Interval mm.	Scale Length mm.	Interval Error mm.
0	0	0	0	0	0
5	5,00000	0	105	105.00050	+0.00050
10	10,00000	0	110	110.00050	+0.00050
15	15,00000	0	115	114.99975	-0.00025
20	20,00025	+0.00025	120	120.00065	+0.00065
25	25,00000	0	125	124.99935	-0.00065
30	30,00000	0	130	129.99975	-0.00025
35	35,00025	+0.00025	135	135.00015	+0.00015
40	40,00050	+0.00050	140	139.99975	-0.00025
45	45,00100	+0.00100	145	145.00015	+0.00015
50	50,00000	0	150	150.00075	+0.00075
55	55,00025	+0.00025	155	155.00050	+0.00050
60	60,00000	0	160	160.00085	+0.00085
65	65,00000	0	165	164.99985	-0.00015
70	70,00000	0	170	169.99935	-0.00065
75	75,00000	0	175	174.99935	-0.00065
80	80,00050	+0.00050	180	180.00000	0
85	85,00025	+0.00025	185	185.00025	+0.00025
90	90,00050	+0.00050	190	189.99925	-0.00075
95	95,00070	+0.00070	195	195.00075	+0.00075
100	100,00070	+0.00070	200	199.99950	-0.00050

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THE MM-100 OPTICAL READING COORDINATE COMPARATOR. NOTES ON FINAL ADJUSTMENT AND ACCURACY TESTS.

Since an unorthodox approach to reducing friction on the comparator ways was used, great care was taken to insure straightness of ways and exactness of the 90° relationship between X and Y ways. Thus, it was felt, any errors due to the low-friction bearing pads would be easier to identify.

An accuracy test made during final assembly showed a precision 0 to 100mm scale measured .016mm too long when measured with the X motion of the comparator. This error was caused by a bowed X way. The error was identified and measured by mounting a sensitive autocollimating telescope on the Y stage of the comparator and autocollimating on an optical flat supported independently from the comparator. Both the comparator and optical flat were supported on the same large surface plate to avoid movement between the two as the X carriage was moved. The optical flat was large enough to allow movement in the Y direction also.

It was discovered that the bow in the X way was introduced by bolting on the back casting. The tests also disclosed that the three feet on which the comparator rests were not well placed to resist twisting from the shifting carriage weight.

The back casting was carefully refitted to the bed casting to eliminate all warping of the X way. The three feet were moved to new positions determined empirically by watching, in the autocollimator, the effect of shifting carriage weight.

To test and adjust the 90° condition of X and Y ways a precision square was clamped to the Y carriage with one blade parallel to the Y ways, and the other blade parallel to the X ways. The parallelism was achieved by placing a sensitive dial indicator (least reading .0001") against the blade to indicate movement as the carriage was moved on the ways. In practice the square is carefully shifted until there is no movement indicated as the carriage is moved along the X ways. The indicator is then shifted to the other blade and the Y carriage is moved without disturbing X. Any movement shown on the indicator is the sum of the errors of the comparator ways and the square. Error in the square is eliminated by flipping it over about an axis parallel to the Y blade and repeating the test. By lapping the bearing pads of the X carriage the ways were brought to the 90° relation with less than 0°, 0', 3" error.

The accompanying tables show the results of tests made during the final checking out of the comparator. The test plate, shown schematically in Fig. 2, was furnished by the U. S. Navy Photographic Interpretation Center. The test scale is a Watts scale similar to the X and Y scales in the comparator.

In all measurements on the test plate each measurement was made three times before moving to the next point on the plate. Each measurement was made with a single micrometer setting.

In all measurements on the test scale, each 10mm line was set on once, and three micrometer settings were made, with the average being mentally calculated and then recorded. Three separate runs were made for each set-up.

Wild Test Plate Furnished by P. I. C.

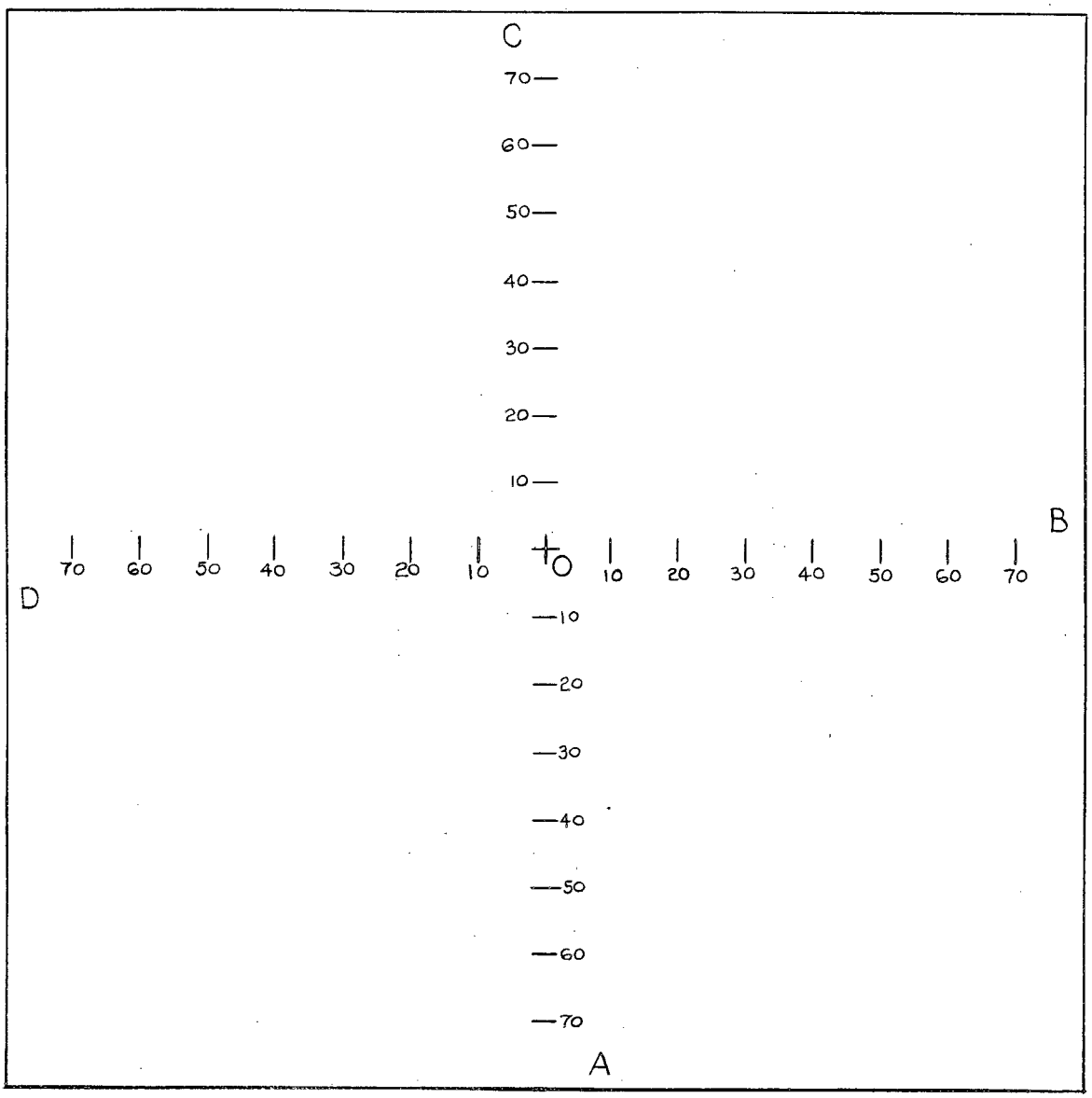


Fig. 2

TABLE I

WILD TEST PLATE MEASURED ON MM-100 COMPARATOR

MM	A	Avg.	B	Avg.	C	Avg.	D	Avg.
0	150.056		50.065		150.061		50.064	
	57		63		61		65	
	58		64		61		65	
		150.057		50.064		150.061		50.065
10	140.057		60.065		160.064		40.065	
	55		64		64		64	
	57		65		64		66	
		140.056		60.065		160.064		40.065
20	130.056		70.066		170.065		30.065	
	59		66		64		65	
	58		66		62		64	
		130.058		70.066		170.064		30.065
30	120.057		80.068		180.061		20.066	
	58		65		62		66	
	58		66		61		66	
		120.058		80.066		180.061		20.066
40	110.054		90.067		190.066		10.066	
	58		69		65		65	
	57		69		66		65	
		110.056		90.068		190.066		10.065
50	100.055		100.067		200.067		0.065	
	57		65		67		67	
	55		69		68		66	
		100.056		100.067		200.067		0.066

TABLE II

MM	A	B	C	D
	0.00*	0.000	+0.002	0.000
10	10.001	10.001	10.003	10.000
	-0.003	0.000	+0.002	-0.002
20	19.999	20.002	20.003	20.000
	-0.002	+0.001	0.000	-0.001
30	29.999	30.002	30.000	29.999
	-0.001	+0.003	+0.002	-0.002
40	40.001	40.004	40.005	40.000
	-0.001	+0.001	+0.003	-0.002
50	50.001	50.003	50.006	49.999

* Error compared to Pic-Wild plate as standard.

TABLE III

WILD CALIBRATION FIGURES FURNISHED WITH TEST PLATE.

MM	A	B	C	D
10	10.001	10.001	10.001	10.000
20	20.002	20.002	20.001	20.002
30	30.001	30.001	30.000	30.000
40	40.002	40.001	40.003	40.002
50	50.002	50.002	50.003	50.001

TABLE IV

X - Y READINGS WITH ENGRAVED SIDE UP. A TOWARD OPERATOR.

	0	Avg.	A-50	Avg.	B-50	Avg.	C-50	Avg.	D-50	Avg.
X	50.065	.065	50.062	.064	100.067	.067	50.050	.049	0.067	.067
Y	150.060	.060	100.056	.057	150.055	.056	200.066	.067	150.055	.056
X	50.065		50.064		100.068		50.050		0.067	
Y	150.060		100.058		150.057		200.067		150.057	
X	50.065		50.065		100.067		50.048		0.066	
Y	150.061		100.058		150.056		200.067		150.056	

TABLE V

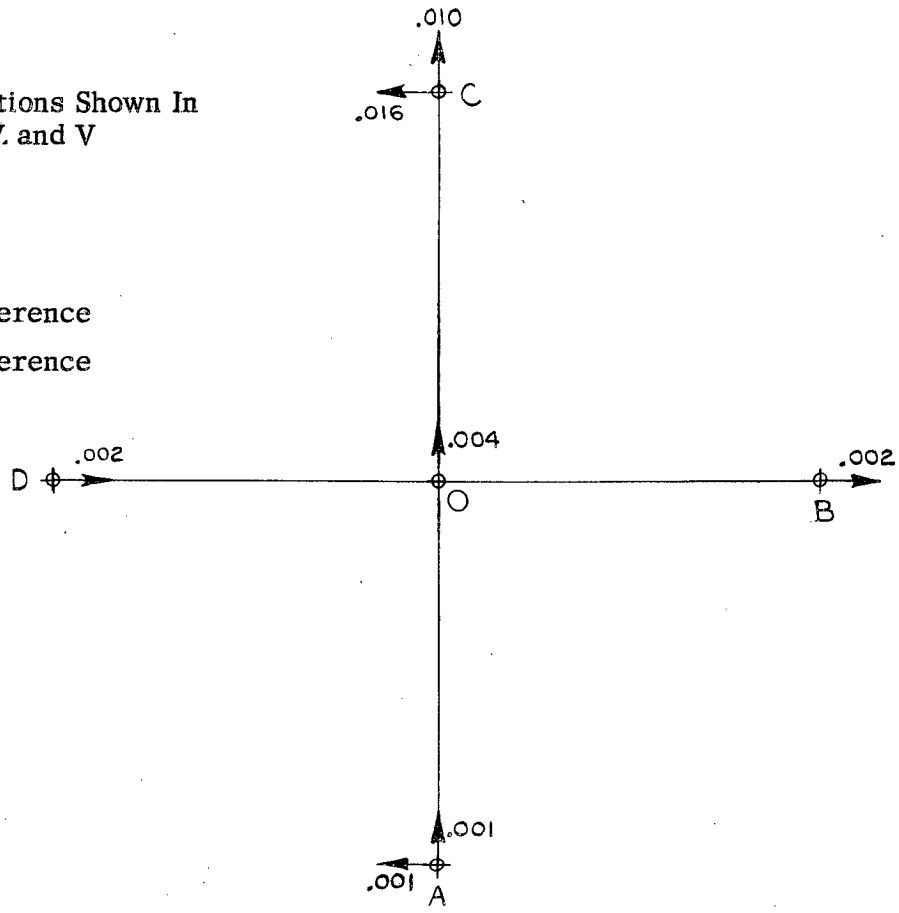
X - Y READINGS WITH ENGRAVED SIDE DOWN. A TOWARD OPERATOR.

	0	Avg.	A-50	Avg.	B-50	Avg.	C-50	Avg.	D-50	Avg.
X	50.106	.106	50.113	.113	0.109	.108	50.114	.114	100.102	.104
Y	150.055	.055	100.050	.050	150.049	.049	200.061	.061	150.049	.049
X	50.016		50.114		0.107		50.115		100.105	
Y	150.057		100.050		150.050		200.060		150.049	
X	50.106		50.112		0.108		50.114		100.105	
Y	150.054		100.051		150.047		200.061		150.049	

Diagram of Positions Shown In Tables IV and V

Line BD = Y Reference

Point O = X Reference



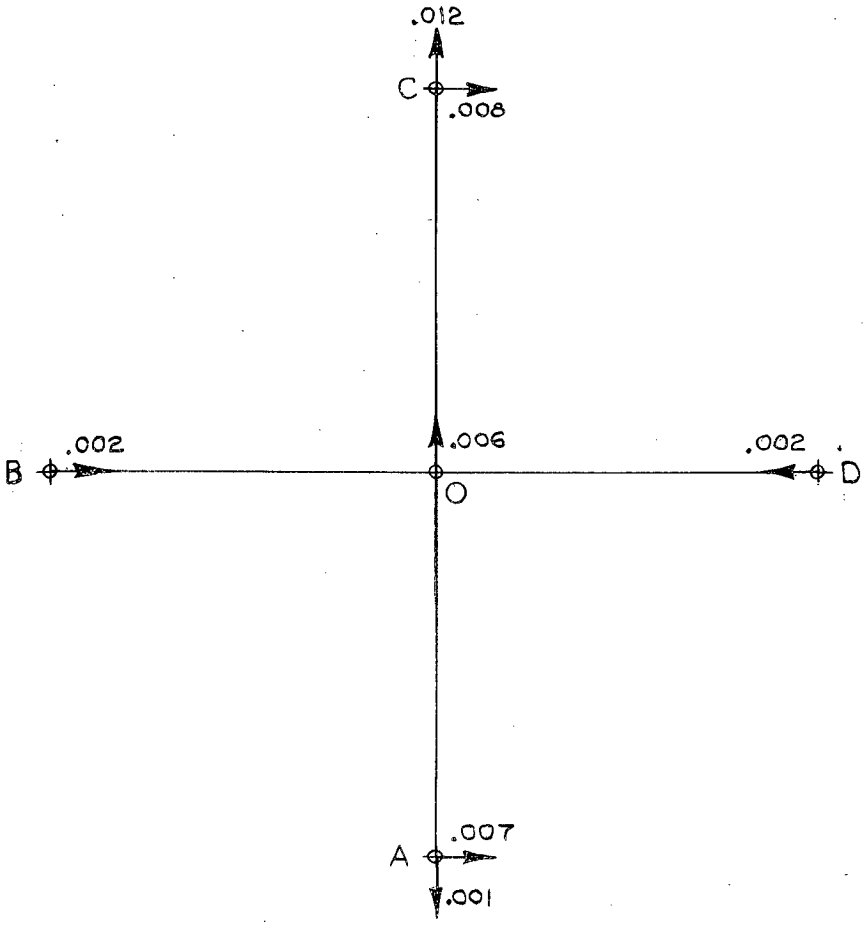


TABLE VI

TEST SCALE MEASURED ON MANN MACHINE #71402

	Back Lighting	Error	Front Lighting	Error
0	29.1545	0.0	31.0505	0.0
10	543	-0.2	503	-0.2
20	550	+0.5	498	-0.7
30	554	+0.9	502	-0.3
40	555	+1.0	502	-0.3
50	553	+0.8	500	-0.5
60	557	+1.2	503	-0.2
70	556	+1.1	498	-0.7
80	559	+1.4	500	-0.5
90	548	+0.3	503	-0.2
100	555	+1.0	515	+1.0

TABLE VII

TEST SCALE MEASURED WITH X, Y SET AT 150MM.

MM	1st	2nd	3rd	Avg.	Error
0	0.070	68	68	68.7	0.0
10	69	68	68	68.3	-0.4
20	68	67	68	67.7	-1.0
30	67	67	67	67.0	-1.7
40	66	66	66	66.0	-2.7
50	65	65	66	65.3	-3.4
60	65	66	66	65.7	-3.0
70	64	64	64	64.0	-4.7
80	66	65	65	65.7	-3.0
90	66	66	66	66.0	-2.7
100	67	67	67	67.0	-1.7

MM				Avg.	Error
100	0.074	73	73	73.3	0.0
90	74	73	73	73.3	0.0
80	73	73	73	73.0	-0.3
70	72	72	73	72.3	-1.0
60	72	72	72	72.0	-1.3
50	71	72	72	71.7	-1.6
40	72	72	71	71.7	-1.6
30	71	71	71	71.0	-2.3
20	72	72	72	72.0	-1.3
10	73	72	72	72.3	-1.0
0	73	73	72	72.7	-0.6

TABLE VIII

Repeat of 1st part of Table VII

MM	1st	2nd	3rd	Avg.	Error
0	0.080	79	78	79.0	0.0
10	79	78	78	78.3	-0.7
20	77	77	77	77.0	-2.0
30	77	77	77	77.0	-2.0
40	76	77	76	76.3	-2.7
50	76	76	76	76.0	-3.0
60	75	76	76	75.7	-3.3
70	75	75	75	75.0	-4.0
80	76	75	75	76.7	-2.3
90	77	76	76	76.3	-2.7
100	77	77	77	77.0	-2.0

TABLE IX

TEST SCALE MEASURED WITH Y, X SET AT 28MM.

MM	1st	2nd	3rd	Avg.	Error μ
0	100.078	77	78	77.7	0.0
10	78	78	78	78.0	+0.3
20	78	78	79	78.3	+0.6
30	78	79	80	79.0	+1.3
40	79	79	79	79.0	+1.3
50	78	79	80	79.0	+1.3
60	79	79	80	79.3	+1.6
70	79	79	79	79.0	+1.3
80	80	79	80	79.7	+2.0
90	79	79	80	79.3	+1.6
100	80	81	81	80.7	+3.0
100	100.085	87	85	85.7	0.0
90	86	85	86	85.7	0.0
80	86	87	88	87.0	+1.3
70	88	89	89	88.7	+3.0
60	87	88	89	88.0	+2.3
50	88	89	88	88.7	+3.0
40	88	88	88	88.0	+2.3
30	87	88		87.5	+1.8
20	88	89		88.5	+2.8
10	88	87	Scale Moved	87.5	+1.8
0	88	90		88.5	+2.8

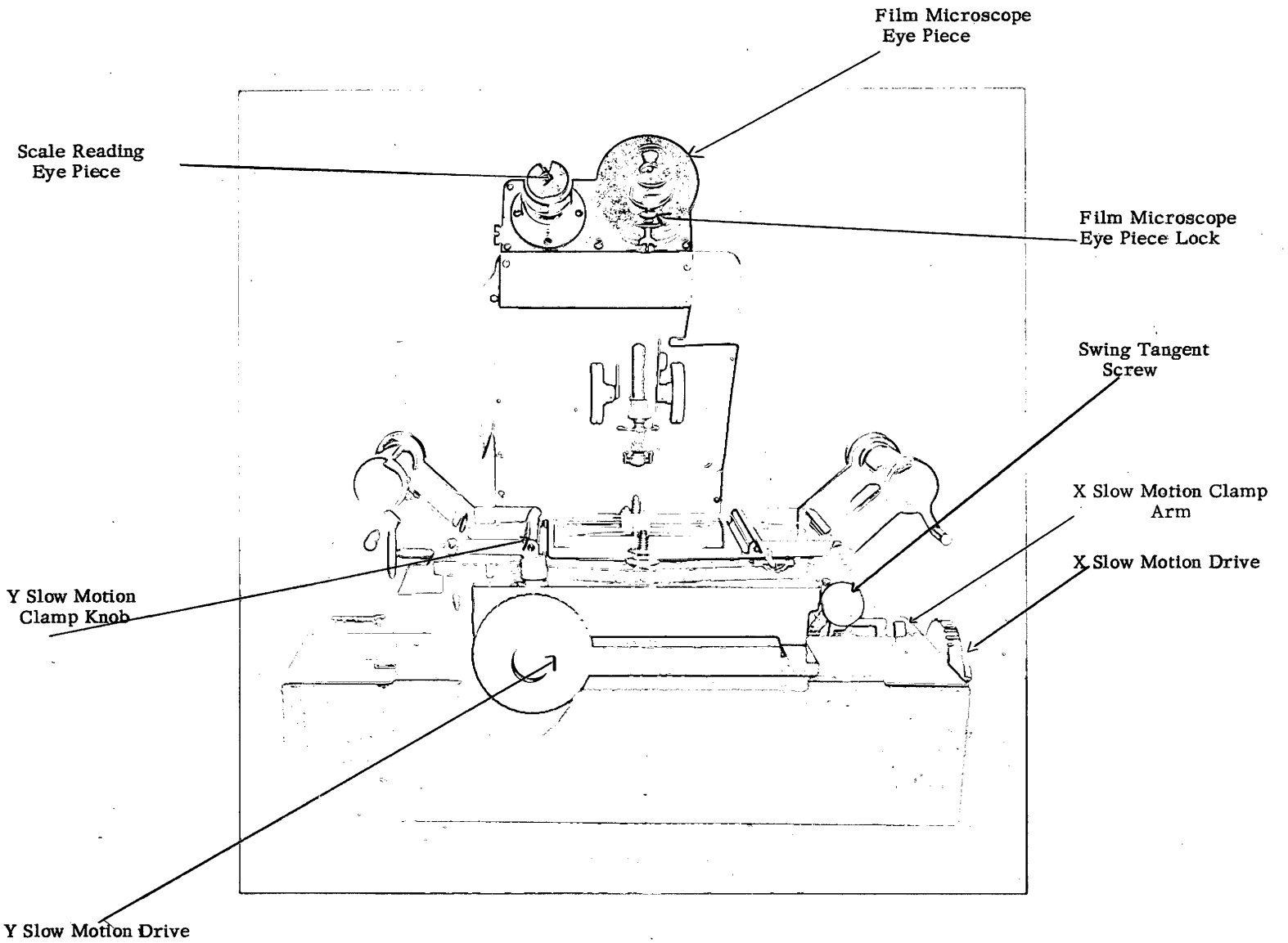


Fig. 4

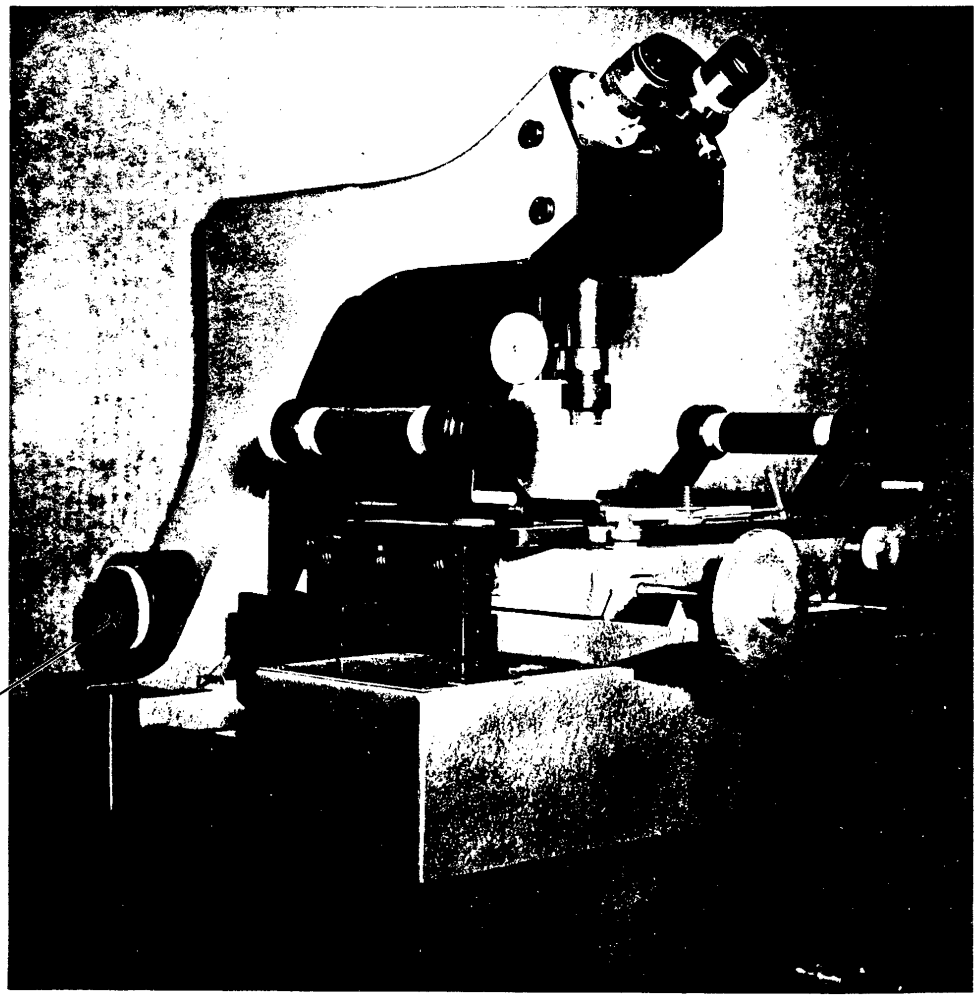


Fig. 5

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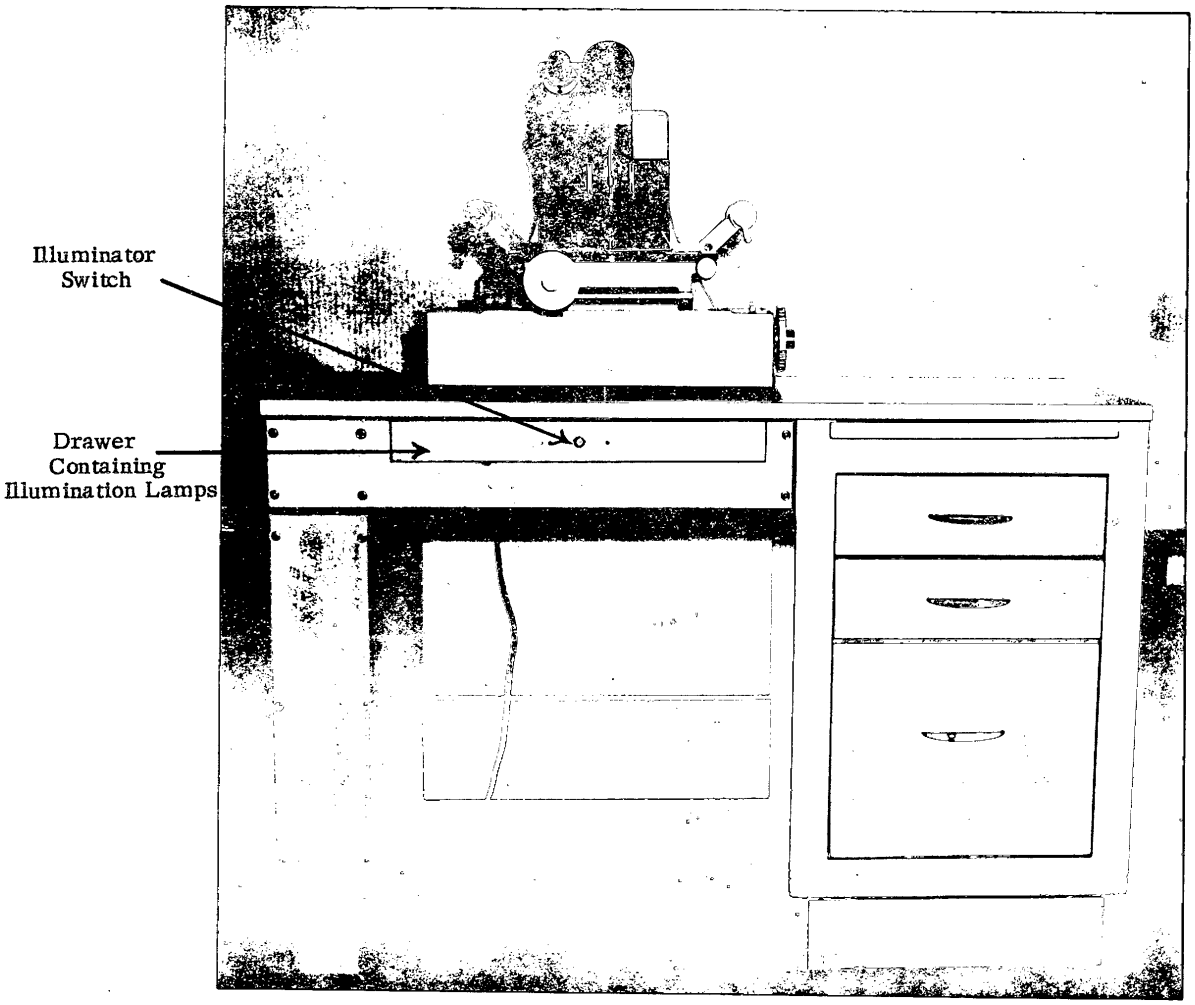

Fig. 6